TEAM PERFORMANCE LAB

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The Study of Crew Coordination and Performance in Hierarchical Team Decision Making

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This report describes the theoretical foundations, methodology, and initial results of an ongoing empirical investigation of team decision making. The theoretical foundations are based on the team process and performance literature, which is discussed in terms of a broad model of team performance. To allow for the measurement of various elements of team performance depicted in the model, a computerized testbed has been developed. This testbed, the Team Performance Assessment Battery (TPAB), includes team and individual tasks arranged according to a synthetic work methodology. Using TPAB, an empirical study has been performed in which team structure and workload were manipulated in a between groups design. The results of this study are interpreted in the context of the team performance model. Implications for future research are also discussed.

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EXECUTIVE SUMMARY

This report describes the theoretical foundations, methodology,
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INTRODUCTION

Recently, a US guided missile cruiser, the USS *Vincennes*, mistakenly shot down an Iranian airbus carrying civilian passengers. Ineffective teamwork was cited as a possible cause of this accident (Congressional Hearings, 1988). Poor teamwork has been implicated in other accidents, as well. For example, Billings and Reynard (1984) contend that a significant majority of accidents in the aviation community occur as a result of ineffective interactions among crew members. As a result of these incidents, much psychological research has been initiated in an attempt to increase the understanding of team performance and team interaction processes. One facet of team performance, tactical team decision making, has emerged as a specific area of interest because of its implication in the incident involving the U.S.S. *Vincennes.* Because there is such a critical dependence on effective tactical team decision making, in both military and civilian teams, it is necessary to develop a thorough understanding of team decision making, the factors that might affect it, and the interventions that can optimize it.

However, the tactical environment is so complex and highly dynamic that it is difficult to provide a thorough analysis of all of the variables that can potentially influence team decision making performance in this environment. Furthermore, a review of the current scientific literature reveals that a full

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understanding of the critical variables and their effects does not currently exist. In fact, it appears that team decision making has been virtually overlooked by the scientific community and that there is a critical need for a programmatic series of research efforts in this area.

The present research effort attempts to contribute to the understanding of tactical team decision making by pursuing three serial goals: 1) considering the existing literature on team decision making performance in light of a theoretical model, 2) using this model to generate hypotheses requiring further investigation, and 3) conducting empirical research to evaluate the resulting hypotheses. This report will describe the theoretical foundations for the current research program and the results of an initial investigation of factors that are hypothesized to influence team decision making performance and processes.

Using a Model-Based Research Approach

An initial objective of this research was to enhance the understanding of team decision making by integrating the available literature into a theoretical model. The utility of such a model lies in the fact that it represents a conceptual framework which can guide the generation of hypotheses and the testing of relationships that might exist between team decision making performance and the various factors that influence it. In

order to fulfill this heuristic purpose, a model must include these two primary components; namely, in its most elemental form, it must represent (a) the behavior(s)/process(es) that are under observation, and (b) the factors that could have some impact upon these behaviors or processes.

Team Decision Making Processes

Identifying the processes[1] that are to be represented in an heuristic model can be thought of as an exercise of setting boundaries. These boundaries serve to separate the processes that are to be studied from those that might be occurring just prior to, during, and/or just after the event of interest. Although such selections are sometimes made arbitrarily, setting these parameters can be very difficult because, in order for these other processes to be excluded, one should be reasonably certain that these temporally-related processes do not influence the process of interest enough to warrant their observation.

The difficulty in setting these parameters is illustrated very clearly in the context of team decision making. Most prior research in this area has focused on the cognitive processes involved in the act of decision making. For example, mathematical modeling has been used to describe the stages of

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[1] The word "processes" is used here to refer to both the general behaviors involved in team interaction and coordination, as well as the psychological phenomena that might not be behaviorally observable (e.g., decision making).

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decision making (Carley, 1991; Levis, 1984; Miao, Luh, Kleinman, & Castanon, 1991). This type of approach uses mathematical techniques to quantify the manner in which group members aggregate the information upon which the decision is based. A number of researchers have also investigated, albeit in a much less quantitative manner, the cognitive processes involved in small group decision making. For example, Laughlin and Ellis (1986) and Levine and Moreland (1990) have examined the decision rules that are followed in order to combine the inputs offered by group members in consensus seeking groups. Similarly, Stasser and Davis (1981) have studied the processes involved in jury deliberation. Janis (1982) has also studied a phenomena called groupthink, which results when group members strive to obtain concurrence at the cost of decision effectiveness.

While these approaches have yielded considerable insight into decision making processes, they seem to have set limited boundaries around the processes of team decision making. That is, they have specifically omitted a careful consideration of the interaction processes (e.g., communication, coordination, cooperation, etc.) that seem to be essential for effective team decision making. In order to understand the broader context of tactical decision making in teams, one must first consider the definition of a team. According to Morgan, Glickman, Woodard, Blaiwes, and Salas (1986), teams are "distinguishable sets of more than two individuals who interact interdependently and

adaptively to achieve specified, shared, and valued objectives" (p.3). Interdependence implies that each team member provides the team with some information or capability, without which the team would be impaired in its ability to accomplish the team-level objective. Such interdependence undoubtedly has a significant impact upon the nature of decision making processes. However, the limitation of the previous research approaches is not that they necessarily overlook interdependence in decision making teams. Rather, they have been limited by their failure to recognize that some team interactions (such as the sharing of information or capabilities to accomplish a team-level objective) are supportive of team decision making even though they don't necessarily feed directly into primary decisions. For example, some team-level objectives require team members to engage in processes such as communication or coordination. Morgan and his colleagues (1986) even suggest that these "teamwork" processes are inherent in all interactive team endeavors. Therefore, it seems reasonable to hypothesize that these coordination processes interact with the more cognitive decision making processes, and that an examination of these factors could provide an enhanced understanding of tactical team decision making.

Thus, the current research approach attempts to extend the boundaries set by other team decision making investigators. Specifically, it includes a consideration of the more global "team processes" (to include team coordination), rather than

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focusing on specific decision processes. As such, the current effort represents a novel model-based approach that attempts to put team decision making into a broader perspective. It is anticipated that this more detailed analysis will both broaden and deepen the understanding of the factors that influence tactical team decision making.

Team Decision Making Variables

In setting boundaries with respect to the variables to be considered in the current research program, a rather broad view has been adopted. As outlined below, broad categories of variables are included in the model to represent the classes of factors that have been found to impact team performance. By selectively examining the effects of specific variables within each of the broad categories, this research seeks to determine the relative importance of the various classes of variables on team decision making performance. Specifically, it is hoped that this approach will set the stage for path-analytic analyses that will evaluate the complex interrelationships among the major variables of consequence to team decision making. It is understood, of course, that the accomplishment of such an objective will require a series of studies wherein one is able to "work one's way up" by empirically combining and testing more and more components of the model. If performed well, the end result of this line of research will be an inclusive model that provides

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a rather extensive capability to understand and predict the effects and interrelationships of the variables that influence tactical team decision making.

The Team Effectiveness Model

The current research approach attempts to incorporate the available literature into a broad-based team performance model. Such a model, called the Team Effectiveness Model (depicted in Figure 1), was proposed by Tannenbaum, Beard, and Salas (In press).

Insert Figure 1 about here

This model presents a classical input-throughput-output representation of the general components of team performance. Input variables include the factors and antecedent conditions that are hypothesized to influence the phenomenon of interest. The phenomena of primary interest here, of course, are the team processes, which are represented as the throughput component of this model. Outputs are the product of the combination of team processes and influential variables. The following sections of this report review the literature relevant to the input, throughput, and output components of the Team Effectiveness Model. In their model, Tannenbaum and his colleagues (In press) depict a component that is referred to as the "organizational and situational characteristics." These characteristics constitute
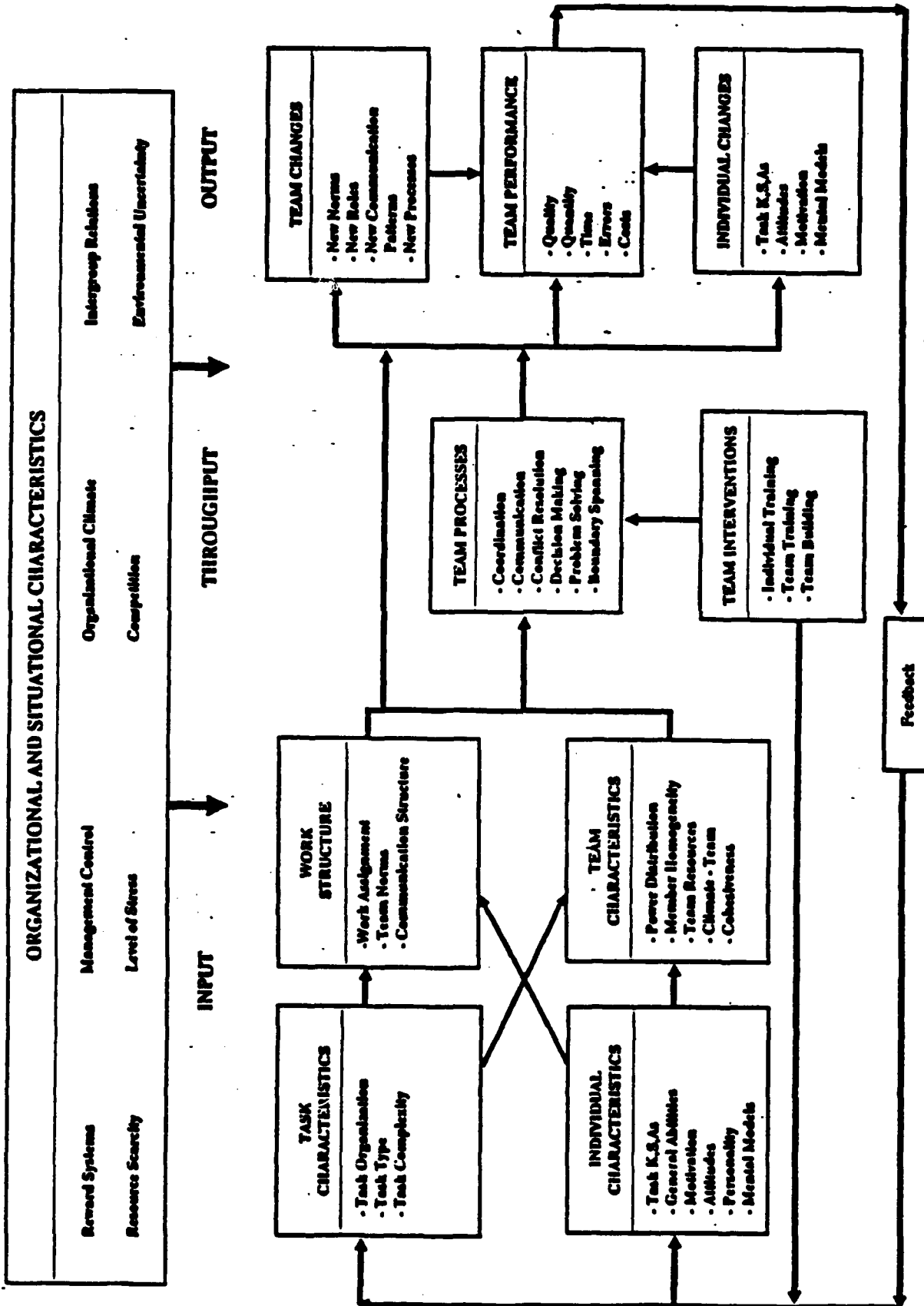
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Figure 1. Team Effectiveness Model (Tannenbaum, Beard, & Salas, In press).

the environmental context in which all team performance events occur. In the current discussion, this context is the tactical environment to which the given research is to be generalized. A review of the literature pertaining to the tactical environment is beyond the scope of the current discussion and will not be specifically addressed here. However, the primary characteristics of the operational context for tactical team decision making has been described by other authors (Athans, 1982; Johnson & Levis, 1989; Orasanu, 1990). Based upon these descriptions, the inputs, processes, and outputs that are addressed in the following sections have been selected because they constitute the essential aspects of the tactical environment that are hypothesized to have an impact upon team performance. Thus, the following discussion attempts to integrate the empirical knowledge that has been gained about team processes and the effects of various factors, acting alone and in interactions with other factors to influence team performance. By integrating the literature into such a broad-based model, hypotheses that require investigation can be identified and empirically evaluated.

Input Variables

As discussed previously, input variables include the stimuli and conditions that are expected to influence team processes and performances. Tannenbaum et al. (In press) categorize these variables into four classes: task characteristics, work

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characteristics, individual characteristics, and team characteristics. Task characteristics include the variables that are hypothesized to affect the team at the level of the individual, while work characteristics are those variables that affect the team at the team level. Similarly, individual characteristics are attributes possessed by individual team members, while team characteristics are the attributes possessed by the team as a whole. These categories of variables are thought to interact, such that task and individual characteristics can each influence work and team characteristics. Thus, in considering the effects of these classes of input variables on team processes and team performance, it is important to consider each category individually and in combination with other categories.

Task Characteristics. Task characteristics are the individual-level variables that constitute the nature of the specific tasks to be performed. The task characteristics of tactical decision making teams include high levels of workload, acute information processing demands, and extreme time pressure. These task characteristics can induce stress in those who are performing in this environment. For example, individuals are often presented with the threat of imminent death, one's own, that of those around them, and/or that of the enemy. Similarly, tactical confrontations are typically quite brief, and split second choices are vitally important. An untimely decision can

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often be just as devastating as an inaccurate one. A great
information processing demand is also inherent in tactical
situations. Highly advanced technological systems that are
currently used in the tactical environment present team members
with a great deal of information to be processed. Thus, when
considered collectively, these task characteristics can
contribute significantly to the stress imposed by operational
environments. A large body of literature exists that discusses
the effects of stress on performance. Summarized briefly, stress
has been shown to have detrimental effects on performance,
specifically on decision making performance (Janis, 1982; Janis
and Mann, 1977). According to Janis and Mann (1977), individuals
experiencing stress tend to miss and/or misrepresent available
information when making a decision. Because the information that
is the basis for decisions is incomplete and/or inaccurate,
individuals often make ineffective decisions.

Another task characteristic that might influence team
performance is workload. The workload experienced by individuals
in a tactical situation can be quite high. Much research has
suggested that high levels of workload lead to degraded
performance (Beith, 1987; Hart & Hauser, 1987; Vidulich & Pandit,
1986). However, the effect of increased workload on team
performance is not yet clear (Morgan & Bowers, In press).
Research suggests that membership in a team alone increases
individual workload beyond that inherent in individual task

demands (Bowers, Braun, & Morgan, 1992; Kidd, 1961; Willeges, Johnston, & Briggs, 1966). Because of such findings, studying the effects of individual workload on team processes is warranted.

Furthermore, it has been hypothesized that the coordination demanded by team tasks increases workload (Bowers, Morgan, Salas, & Prince, in press; Kidd, 1961). However, Kleinman and Serfaty (1989) suggest that team members may adapt their behavior in response to increased workload. In the studies performed by Kleinman and Serfaty (1989), workload is a team level manipulation. Therefore, this concept is discussed more thoroughly in the context of work characteristics.

Work Characteristics. The work characteristics of a team are primarily related to team structure in terms of the assignment of sub-tasks or roles to individuals in the team. One study that addresses this assignment of tasks was performed by Kleinman and Serfaty (1989). These researchers manipulated the team's work structure in terms of the degree to which overlap existed among individuals' tasks in a two-person resource allocation task. In this case, overlap refers to the sharing of task responsibility and information among team members. It has been hypothesized that overlap might blur boundaries that exist between team members (particularly those that might exist between the decision executor and subordinate team members), and hence, perhaps reduce the possibility of error. However, in a complex

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environment (e.g., a command information center) each person's task is so highly technical that task overlap might overwhelm the members of a team. Thus, it is important to determine how much (if any) task overlap might be associated with improved decision making.

Kleinman and Serfaty (1989) found that under low and moderate levels of workload, more task overlap resulted in better performance. Under high workload, however, partial task overlap was associated with the best team performance. The authors suggest that under high workload, a high degree of overlap floods team members with more information than they can assimilate. Hence, partial overlap allows for optimal performance in this situation.

In the tactical decision making team, however, roles are typically assigned according to a hierarchical structure (i.e., the chain of command). In hierarchical teams, decision making is a diffuse procedure wherein relevant information is distributed among team members (Connolly, 1977). Because information is distributed, team members must (a) effectively gather all information available to them that impacts upon their particular sub-task function, (b) determine the amount of information that should be passed on to the rest of the team, and (c) communicate the chosen information effectively. In military environments, information and responsibilities are usually distributed according to a hierarchy. That is, information and sub-task

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functions are distributed such that a leader is given various pieces of information from subordinate team members and he/she must execute decisions based on this information (Coovert, Cannon-Bowers, & Salas, 1990).

A situation like the one described above, with subordinate information gatherers and a superordinate decision executor, can be thought of as a two-tiered decision hierarchy. In such a structure, errors can be made at either (or both) levels. On the subordinate level, errors are likely to result if too little information is passed along to the leader. In addition, if too much information is passed along to the leader, he/she might fail to focus on the information that is most pertinent to the decision at hand, because he/she was overwhelmed by the excess information. Many similar possibilities for error also exist on the superordinate level. For example, the leader might disregard information which is relevant to the decision, or commit the opposite error, considering information that is actually irrelevant to the decision. In tactical environments, more than two (i.e., subordinate and superordinate) structural levels often exist in given decision hierarchies. It could be hypothesized that these additional tiers of structure will exponentially increase the opportunity for team error.

Information and sub-task functions, however, are not only distributed hierarchically among tactical decision making teams. Within the same hierarchical level, information and capabilities

are distributed across team members. These individuals are required to coordinate in order to integrate their efforts to further the team in the achievement of its objective. According to Vaughn (1990), "Coordination is the price to be paid for the advantage of having a complex problem decomposed into manageable parts. The boundaries of the parts specify where coordination may be required, and the nature of the interactions between parts suggests how much or how critical the coordination" (p. 13). Obviously, the specific architecture (i.e., structure) according to which information and responsibilities are distributed (both across and within hierarchical levels) can have an impact upon team performance. Therefore, one would want to know which architectures would optimize performance in various types of tasks. Simon (1969) asserts that when decomposing a system into various subsystems, the best architecture is one that minimizes the interactions that are necessary among the various parts. However, given the complexity of most systems, finding the optimal architecture(s) is nearly impossible (Simon, 1969; Tsitsiklis & Athans, 1985). Therefore, much of the research being performed in this area uses mathematical modeling in an attempt to identify satisficing designs (Vaughn, 1990).

Empirical work has also been conducted to determine the effects of team structure on decision making. In summary, this research indicates that the effects of hierarchical structure on tactical team decision making performance are not fully

understood. Much of this literature deals with team autonomy, which according to Sundstrom, De Meuse, and Futrell (1990) refers to the degree to which leadership and authority are centralized or distributed among group members. For example, highly autonomous groups, which decide upon their own leadership, as well as on the distribution of responsibility among group members, have been studied by Pearce and Ravlin (1987). Cherry (1982) has studied semi-autonomous groups (i.e., groups with a designated leader) working in the automotive industry. In general, these studies conclude that the effect of work structure, in and of itself, is difficult to ascertain because it appears to interact with other variables such as leadership style and workload.

Furthermore, the paradigms used in these and other similar decision making studies prevent generalizability to tactical decision making teams. These organizational studies often measure team outputs according to the extent to which an investment or return is maximized. In order to approach a maximum output, a certain amount of error is often necessary, or at least tolerable. However, given the nature of the tactical environment, error is simply unacceptable. Therefore, results of studies which assess performance by optimization of outcomes might be inappropriate for use in this area.

Individual Characteristics. Individual characteristics refer to the skills, knowledge, and personalities of the

individuals in the team. Because of the great extent to which military personnel are trained before being placed in a tactical environment, skills and knowledge of members of military teams are not included in the present discussion. However, the influence of personality factors and attitudes on team performance does warrant discussion. In the available literature, there is disagreement concerning whether or not the personality of individuals influences team performance. Kahan, Webb, Shavelson, and Stolzenberg (1985) contend that personality traits are general constructs, and therefore, cannot predict team performance on specific tasks. The position is based on studies such as those conducted by Bouchard (1969), Butler and Burr (1980), and Haythorn (1953), which demonstrate weak, if any, support for the relationship between various aspects of personality and performance.

Research does exist, however, that offers support for this relationship. For example, Haythorn, Couch, Haefner, Langhan, and Carter (1956) demonstrate that significantly different behaviors were exhibited by authoritarian and nonauthoritarian teams. Furthermore, various measures of personality have been shown to predict the attitudes and coordination behaviors exhibited by aircrews (Gregorich, Helmreich, & Wilhelm, 1990; Helmreich, 1987; Spence & Helmreich, 1978; Spence, Helmreich, & Pred, 1987). The success of Helmreich and his colleagues in supporting the relationship between personality and performance

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illustrates the need for further research to determine the degree to which the findings obtained with aircrews can be generalized to teams in other operational environments.

Team Characteristics. Team characteristics (i.e., those characteristics that distinguish a particular team), can also influence team processes and team performance. According to Morgan and Lassiter (1992), the team-level variables include "factors which cannot be accounted for in terms of a single individual, but which require the interaction of two or more team members" (p. 24). Several variables, whose effects on team processes and team performance have been studied extensively, will be discussed briefly in order to summarize the available literature on team characteristics. These variables are team size, compatibility, and cohesion (Bass, 1982; Moreland & Levine, In press; Morgan & Lassiter, 1992).

To a large extent, task demands determine the optimum number of individuals performing as·a team (Bass & Ryterband, 1979). However, the effects of team size have been studied extensively, and results indicate that adding team members has proven to be both beneficial and detrimental with respect to team processes and performance (Moreland & Levine, Ir press). The beneficial effects of adding individuals to teams have been illustrated by Cattell (1953) who found that larger teams had higher skill levels and more diverse information processing capabilities than smaller teams. These positive effects may arise because each

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additional individual brings additional performance resources to the team (Shaw, 1976). However, Morgan, Coates, and Rebbin (1970) report that the performance of five-person teams experiencing illness was better when one person was absent than when all five team members participated. The negative effect on team performance associated with increased size may arise because larger teams have the potential for more interactions among individual team members, thus resulting in performance that is slower and less accurate (Bass, 1982). Furthermore, increased team size has been associated with decreased communication (Indik, 1965), feelings of inhibition to participate (Gibb, 1951), and greater conformity (Shaw, 1976; Gerard, Wilhelmy, & Conolley, 1968). When applied to decision making teams, these behaviors exhibited by large teams "might serve to limit the amount of information utilized in arriving at a decision" (Morgan & Bowers, In press, p. 19). Morgan and his colleagues (Morgan, & Bowers, In press) contend that further empirical study is necessary to determine the effects of team size on decision making performance.

Compatibility among team members is also an important team level factor to be taken into consideration. Compatibility is discussed in terms of homogeneity versus heterogeneity among team members. In general, heterogeneous teams (with respect to abilities and interests) are more likely to experience conflict among team members than homogeneous teams (Bass, 1965; Hoffman,

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1959), while homogeneity seems to enhance team interaction (Bass, 1982). However, the effects of homogeneity versus heterogeneity are moderated by the type of task being performed. For example, Lodahl and Porter (1961) found that cooperation among team members performing a complex physical task was greater in homogeneous teams than in heterogeneous teams. In problem solving tasks, the effect of compatibility is reversed: heterogeneity appears to facilitate performance (Bass & Ryterband, 1979; Hoffman & Maier, 1961). Morgan and Lassiter (1992) suggest that "the high degree of similarity of members in homogeneous teams often acts as an obstacle to creative and thorough solutions because of the team's relative lack of breadth and variety of resources" (p.35). These observations made on team composition, however, are based on research performed in controlled environments. These findings must be tested in more naturalistic situations to determine their generalizability (Morgan & Bowers, In press).

The third team characteristic variable to be discussed is cohesion. Tannenbaum and his colleagues (In press) describe team cohesion as "a team's feeling of belongingness and sense of teamness" (p. 124). Although a large literature on team cohesion exists, the nature of the relationship between team cohesion and performance is unclear. In general, this relationship is much like the "chicken and the egg" phenomenon. For example, Shaw (1976) suggests that performance is enhanced by high cohesion.

Anderson (1975), on the other hand, illustrates that successful team performance increases cohesion. With respect to team decision making performance, a review by Wolfe and Box (1988) suggests that much of the research that has been conducted does not support a strong relationship between cohesion and team decision making performance. Wolfe and his colleagues (Wolfe et al., 1988) suggested that motivation must be taken into account when attempting to discern this relationship. These researchers empirically demonstrated a strong relationship between cohesion and team decision making performance under a high degree of motivation. While the exact nature of the relationship between cohesion and performance remains unclear, the available findings suggest that cohesion seems to be an influential variable, and hence, should be further investigated.

The present study attempted to consider the effects of six input variables: workload, task structure, attitudes towards coordination, cohesion, teamness, and familiarity upon team processes and performance. Analysis of these variables will serve as a preliminary test of the theoretical model described by Tannenbaum and his colleagues (In press).

Throughput

Team Processes. Team processes are the interactions among team members that allow them to accomplish the team's common goal. These processes are also referred to as teamwork (Glickman, Guerette, Campbell, Morgan, & Salas, 1987) or crew

coordination (Franz, Prince, Cannon-Bowers, & Salas, 1990). Although as much as fifty percent of the variance in team performance can be accounted for by attributes of the particular task being performed (Hackman, 1968), one of the goals of team research is to determine how much of the remaining variance is attributable to teamwork. It is hypothesized that the nature of these team activities is similar across all types of teams, performing any type of task. Before this hypothesis can be tested, however, the behaviors that constitute this elusive concept must be identified.

The empirical work performed by Glickman and his colleagues (1987) suggests that teamwork includes seven general dimensions of behaviors: communication, coordination, team spirit and morale, giving suggestions and criticism, acceptance of suggestions and criticism, cooperation, and adaptability. In a study with Naval Gunfire Support teams, over ninety behaviors were classified within these seven categories (Glickman, et al., 1987). Based on frequencies of these critical behaviors, effective teams could be distinguished from ineffective teams (Glickman, et al., 1987).

The concept of teamwork has also been addressed by Orasanu (1990) in a study of team decision making in aircrews. This researcher suggests that team-level interaction processes involve the following: communicating to arrive at a common understanding of the problem at hand, strategizing about possible solutions,

and communicating about the responsibilities of the various team members in dealing with the problem. Engaging in these activities is believed to foster the development of a "shared mental model" of the situation. In this context, teamwork can be conceptualized as those interpersonal interactions that allow team members to arrive at this shared mental model. After arriving at a shared mental model, team members must also interact in order to allocate relevant information and responsibilities to individual members of the team. This process is referred to as resource management (Orasanu, 1990).

In a previously described study of team decision making, Kleinman and Serfaty (1989) further elucidate the team processes involved in decision making performance. In this study, teams exposed to low and moderate levels of workload exhibited frequencies of team communication that were significantly higher than those exposed to high workload levels. However, the level of team coordination (as observed through the number of resource transfers) was maintained. Under lower workload levels, teams were said to "explicitly coordinate." That is, each transfer was likely to be preceded by a specific request. Because of the decreased frequency of team communication under high workload levels, the coordination of these teams was described as implicit; transfers were made without a request. For the purposes of the present research, throughput will be assessed via communications analyses.

Output Variables

Output variables include the measures that reflect the results of team processes, in light of the acting influential variables. The current research approach focuses on team performance as the main outcome of interest. According to Tannenbaum and his colleagues (In press), team performance includes "quantity and quality of products and services, as well as time, errors, costs, and overall productivity." (p. 10) The Team Effectiveness Model (Tannenbaum, et al., In press) also includes individual changes and team changes as additional outcomes. These two types of outcomes illustrate the dynamic nature of the team and the individuals of whom it is composed, and hence, represent a useful inclusion in the model. Specific assessments of these outputs need to be included in future research.

·Summary

While the available literature provides some insight into the variables and processes that are likely to influence team decision making performance, the nature and generalizability of these effects, acting individually and collectively, are unclear. The input variables that are of interest in the context of tactical team decision making are individual workload, team workload, hierarchical structure/task overlap, attitudes toward coordination, cohesion, teamness, and familiarity. The team

processes of interest are decision making, coordination, and communication. The relevant outcomes are team performance (as reflected by measures of quality, quantity, time, and errors of performance), individual changes, and team changes. Further research is needed in order to evaluate these elements in light of the Team Effectiveness Model.

Purpose of the Current Research

As illustrated in the previous section, the available research in the area of tactical team decision making is insufficient to evaluate the utility of the Team Effectiveness Model in understanding this type of team performance. Thus, there is a need for a program of research designed to investigate those variables which, as suggested by the model, might contribute to a thorough understanding of team decision making.

The current research attempted to address this need by investigating the team process and outcome consequences of manipulations of two types of work characteristics variables (hierarchical structure and team workload). In other words, this research addresses the following questions: (a) does the way in which teams are structured (i.e., the amount of task overlap and/or task specialization) affect the performance of teams in which members are required to perform both individual and team level tasks? and (b) how are these effects influenced by the level of team workload?

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The current study compares the performance of teams organized according to a horizontal (non-hierarchical) arrangement to those in a vertical (hierarchical) structure. This research uses a resource allocation task similar to the one employed by Kleinman and Serfaty (1989), except that the current task utilizes five-person teams. Team members assigned to the horizontally structured condition were presented with identical information and capabilities with respect to performing the team task. Team members assigned to the vertically structured condition were presented with only the information and capabilities necessary to allow each of them to perform a specialized component of the overall team task.

Both versions of the resource allocation task were presented along with individual monitoring tasks in a manner consistent with the synthetic-work methodology (Alluisi, 1967; 1969). This approach enhances the generalizability of the study's results to the operational environment because subjects were required to trade-off or time-share individual and team-level duties. By requiring subjects to perform several tasks concurrently, workload levels analogous to those found in operational environments were simulated (Morgan & Alluisi, 1972). The tasks created a synthetic job that provides efficient performance measures and places cognitive demands on subjects that are similar to the demands placed on team members in tactical settings (Bowers, Morgan, & Salas, 1989).

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Method

Subjects

Twenty-four 5-person teams of undergraduate students from the University of Central Florida voluntarily participated as subjects in this experiment. Teams were assigned to one of four experimental conditions (2 x 2 factorial design, workload by team structure) such that six teams participated in each condition.

Tasks

Computerized network. The tasks performed by subjects were incorporated into a team performance assessment battery (TPAB) that was functionally and conceptually similar to the Multiple-Task Performance Battery (MTPB) which was developed earlier by Alluisi and his colleagues, and which served for many years as the definitive test-bed for individual and group performance (Alluisi, 1967, 1969; Morgan and Alluisi, 1972; Morgan, Coates, Kirby & Alluisi, 1984). The TPAB was developed using a Novell Local Area Network (LAN) consisting of six Gateway 80386-based PC's linked via a linear bus topology, a configuration chosen for its efficiency and economy. A graphic representation of the TPAB hardware design is illustrated in Figure 2.
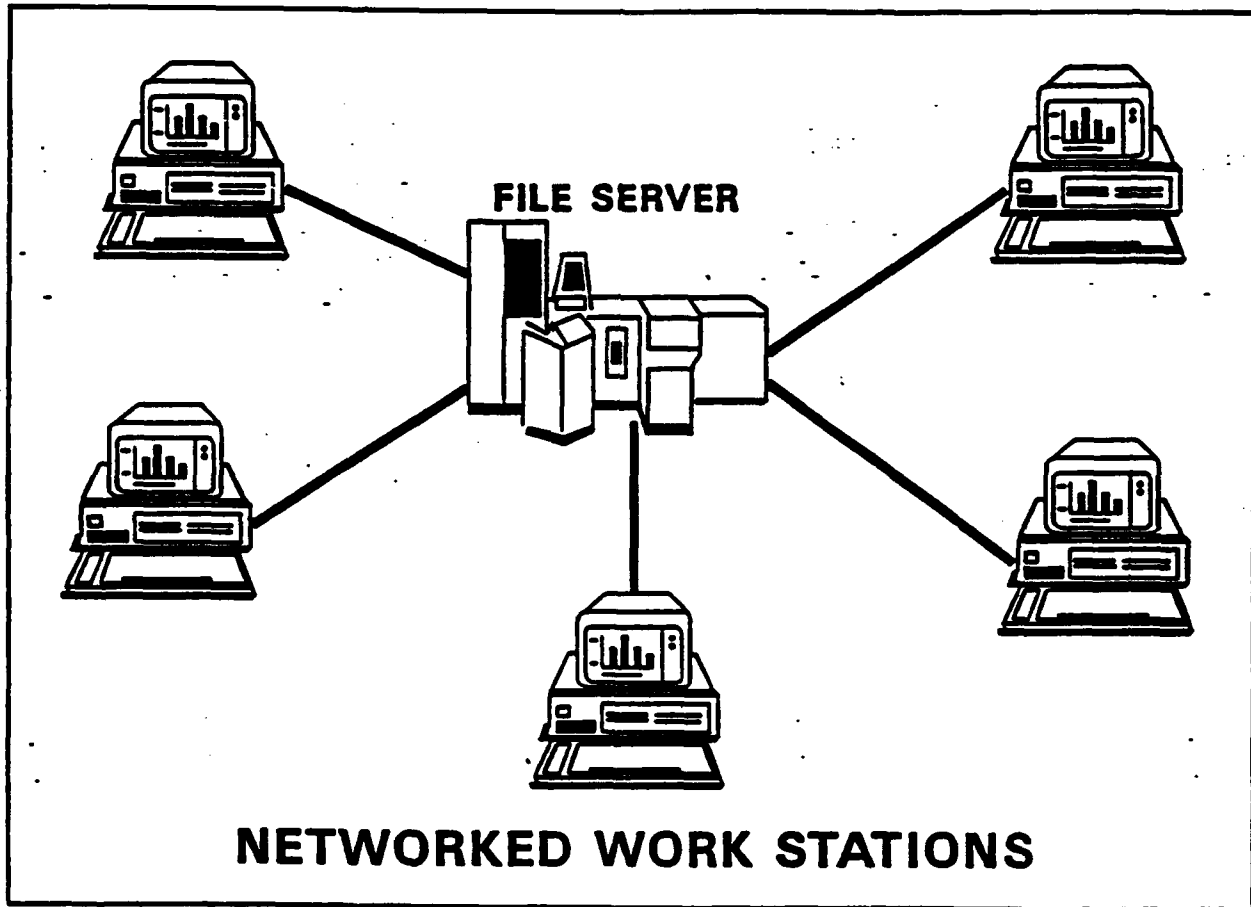

Insert Figure 2 about here

As indicated in Figure 2, five of the computers were dedicated as work stations for experimental subjects while the

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Figure 2.   Hardware of the TPAB network.

**FILE SERVER**

NETWORKED WORK STATIONS

sixth served as the file server. The five work stations were identically equipped, each with 4 mB of RAM, a 1.44 mB floppy disk drive and a 20 mB hard disk drive. The file server utilized 8 mB of RAM and was equipped with a 340 mB hard disk. Communications among the work stations and file server were handled by Novell Netware installed in the file server and ARCNET-PC210 network controller boards installed in all six PC's. The five work stations were loaded with MS-DOS and the NET3 and IPX portions of the Netware shell. The file server contained both the Netware shell and operating system. Amdek 722 monitors were interfaced with each computer via Vega deluxe graphics adaptor boards. The person/machine interface was accommodated by mouse. Interpersonal interactions among team members were recorded (i.e., videotaped) permitting analysis of team communications. Schematic representation of the TPAB team and individual tasks is presented in Figure 3.

Insert Figure 3 about here

Watchkeeping tasks. Three individual performance tasks were selected to provide a continuous background of low-level performance demand against which the team tasks are to be performed. These tasks were adapted from the Multiple-Task Performance Battery where they provided measures of watchkeeping,
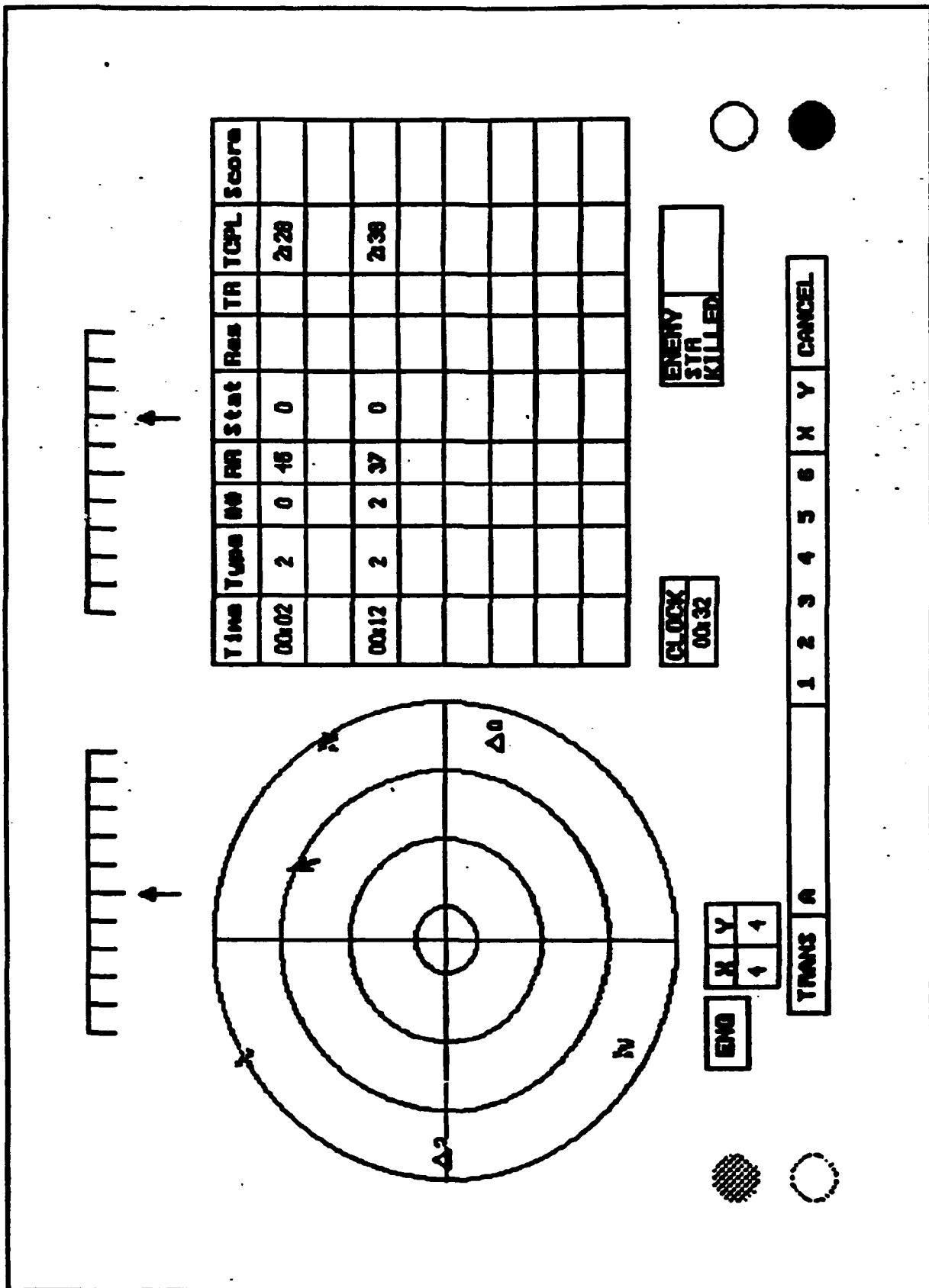
Figure 3. Schematic representation of TPAB individual and team tasks.

vigilance, and attentive functions (see Alluisi, 1967, 1969;
Morgan & Alluisi, 1972). Critical signals were scheduled
independently on each of the three tasks according to a half-
normal distribution with intersignal intervals that ranged from
300 to 800 seconds as follows:

Intersignal Interval (sec)	Frequency in two hour trial
250	4
300	3
350	3
400	2
450	2
500	1
600	1
650	1
800	1

The three tasks were performed concurrently and continuously
during any performance session. Therefore, they may be treated
collectively as a single low-demand individual performance
requirement to which each operator responded independently.
Because most team performancè situations require team members to
attend to individual-performance requirements as well as team-
performance activities, and because monitoring is a basic
functional requirement in most work situations, the inclusion of
these tasks was expected to enhance realism and operational
relevance.

Warning-lights monitoring. As shown in Figure 3, the
warning-lights monitoring task (Morgan & Alluisi, 1972) was
presented by using a pair of simulated warning lights, one green

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and one red, located in the lower left periphery of the computer display. These images were created using direct video buffer read/writing by a high-level graphics generation program. Created images were stored in the computer's memory and recalled by the TPAB as needed. The subject was instructed that the task was in a "normal" state when the green light was on and the red light was off. At random intervals of time there was a change of state in one of the two lights so that either the red light went on or the green light went off. This change indicated a critical condition to which the subject was to respond as quickly as possible. Subjects responded through a mouse interface by dragging the cursor to the illuminated red light or the unlit green light and clicking the mouse in order to turn the red light off or turn the green light on. The subject's response time (latency to .01 sec) to the critical condition was the primary dependent variable to this task. If a subject failed to respond within two minutes, the non-normal condition was corrected automatically and he/she was given a score equal to the maximum latency (120 sec).

Blinking-lights monitoring. The blinking-lights task (Morgan & Alluisi, 1972) constituted the second of the individual watchkeeping tasks in the TPAB. This task was presented via two vertically arranged amber "lights" in the lower right periphery of the display. These simulated lights were generated in an identical manner as in the warning-lights task. Under normal

conditions, the two lights alternated flashing at an overall rate of two flashes per second. The critical condition for this task occurred when one light (either the top or the bottom light) turned off and the other flashed at twice the normal rate (i.e., the overall flash rate remained constant). The duration of each flash, both in the normal and arrested conditions, was 0.25 seconds. The subject was required to respond to the critical condition by dragging the cursor to the blinking light and clicking the mouse. Response latency (to 0.01 sec) to the critical condition was also the dependent variable for this task. If a subject failed to respond within two minutes, the non-normal condition was corrected automatically and he/she was scored with a maximum latency (120 sec).

Probability monitoring. The third of the watchkeeping tasks was the probability monitoring task. In this task, two linear scales were located along the top portion of the display. A pointer on each scale was driven by a random-generator that was updated twice per second. The graphic presentation of this task was also controlled by the graphics generating program. Pointer settings were normally distributed with a mean of zero (i.e., average location corresponds to the center of each scale) and a standard deviation of 1.0 scale unit. At randomly selected intervals, the program introduced a "bias" to the distribution of pointer settings so that the mean of the distribution on one of the two scales shifted one standard deviation to the left or the

right of the center of the scale. This biased condition represented the presence of a critical signal. In performing this task, the subjects were required to detect the presence of a bias in the pointer settings and respond so as to correct (or remove) the biased condition. When a bias was detected, subjects responded with the mouse by dragging the cursor to a designated spot on the left- or right-hand side of the biased meter (i.e., a response was made to the left if a bias-to-the-left was detected, and a response was made to the right if a bias-to-the-right were detected). If a bias was present and a correct response was made, the pointers of both scales froze in their position for six seconds. If a response was made in the absence of a bias, the movement of the pointers was not interrupted. Data recorded on this task were the number of bias signals presented, the number of signals detected correctly, the number of false responses, and the time required to detect each critical signal.

Team Resource Management (REMAN) Task. The resource allocation task in the TPAB was a modification of the Distributed Resource Allocation and Management (DREAM) task (Kohn, Kleinman, & Serfaty, 1987; Kleinman & Serfaty, 1989). This task was designed to assess team skills such as communication, decision making, coordination, and resource allocation in a naval warfare simulation. The DREAM task had been used in several studies to assess team decision making and resource allocation skills and appeared to be of a sufficient difficulty to elicit high-level

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coordination behaviors from team members (Bushnell, Serfaty, & Kleinman, 1987; Kohn, Kleinman, & Serfaty, 1987; Kleinman & Serfaty, 1989). As modified in the TPAB, the resource management (REMAN) task was presented to teams of five subjects via two different displays in the center of the screen. A schematic representation of these displays is shown in Figure 3. One display was a graphically simulated radar display. The center of this circular display was designated as "home base." The home base was circled by three rings which indicated the distance of a threat from the home base. The second major part of the REMAN display was a table which provided text relating to information about approaching threats and amounts of resources available for use. This table included information concerning the current time, expected penetration time for each target, target type and identification number, type and number of resources required to destroy each target, the status of each target, resources to be returned to the team, and target score.

In this task, teams were required to utilize the information from their computer displays in order to manage collective resources and coordinate their actions in order to destroy incoming enemy targets. Each team had a limited number of two different types of renewable resources with which to engage the targets. Team members were able to transfer these resources among themselves as required. There were three different types of targets, each requiring a different number and type of

resources to destroy it. It was the team's task to manage the allocation of available resources so as to destroy the maximum number of targets. Targets appeared randomly in any of the three distance rings and moved toward home base at a constant rate. Each target required 30 seconds to be destroyed. No target had an availability of less than 50 seconds. Thus, team members were required to be aware of both the availability of resources as well as time demands impacting on those resources.

Furthermore, there were three sub-tasks that constituted REMAN performance. The first sub-task tapped the team's situational awareness by requiring members to monitor a simulated radar display for incoming enemy targets. The second sub-task required team members to decide how to allocate and manage the resources necessary to engage enemy targets. In the third sub-task, team members used the resources allotted to them in order to engage (shoot down) enemy targets.

Enemy targets appeared first as vague ("fuzzy") images on the radar scope. To perform the first team sub-task, subjects used the mouse to click on these images. Once clicked on, information pertaining to the resources required and length of time available to prosecute a target appeared in the data table. To perform the second team sub-task, subjects used the mouse to click on specific areas of the display to transfer resources to one another. To perform the third team sub-task, subjects holding an appropriate number of resources clicked on specific

areas of the display to shoot down the enemy target.

For purposes of the present research, the team task was arranged according to one of two structures; namely, horizontal and vertical structures. In the horizontal structure, each team member was presented with identical information and capabilities for performing the team task. In the vertical structure, team members were provided with limited information and capabilities, and therefore, each could only perform one specific sub-task function. Three team members were assigned the role of scope operator. Each of these team members were required to monitor their radar scope for one particular type of enemy target. One team member was assigned the role of resource allocator. This team member was presented with all information, but only resource allocation capabilities, pertaining to the team task. One team member was assigned the role of target engager. This team member was given the task of shooting down enemy targets.

Teams within each task structure performed at two levels of workload, low and high. Low and high workload teams were given the same number of resources for performing the team task. However, workload was manipulated by changing the mean and upper limit of the average number of resources required in order to engage enemy targets. That is, each team was given 40 resources (twenty of each of the two types, X and Y). For low workload teams, the distribution of the resources required to engage targets ranged from one of each type (i.e., 1 X and 1 Y resource)

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to seven of each type, with the mean of the distribution at 5 X and 5 Y resources. For high workload teams, the distribution of the resources required to engage targets ranged from 1 X and 1 Y to 9 X and 9 Y, with the mean of the distribution at 7 X and 7 Y resources.

Procedure

Upon arrival, each subject filled out a consent form. After the arrival of all five team members, subjects were asked to fill out two questionnaires. One questionnaire assessed the degree to which each subject was familiar with each of the other team members. The other questionnaire assessed individuals' attitudes toward team coordination. Upon completion of these questionnaires, each team was given one hour of training before performance was recorded. The materials used for this training were an interactive computerized tutorial accompanied by an experimenter's script. Subjects were given verbal instructions about actions that needed to be taken to perform each of the three watchkeeping tasks. After each task description, subjects were prompted to interact with TPAB to correct all possible stimulus conditions in each of the three individual tasks. Following this portion of the tutorial, subjects were asked to monitor all three individual tasks simultaneously for ten minutes. Subjects were also informed that stimulus states to which they must respond appeared much more frequently during this practice session than they did during the actual experimental

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session. After completion of this practice, subjects were given
instructions pertaining to the team task. Subjects were given a
verbal description of the objectives of the team task, as well as
how to perform each of the three team sub-tasks. The
computerized tutorial then presented the team with several
targets, allowing for a "walk-through" of target prosecution and
resource allocation. In this interactive REMAN training session,
each team member was presented with identical information and
capabilities for performing the team task (i.e., all teams were
trained in the horizontal condition). By presenting each team
member with all information and capabilities necessary for
performing the team task (i.e., by giving full task training),
all subjects were given an overview of all aspects of the team
task. After performing this interactive training session,
vertical teams were given a verbal description of how the three
team sub-tasks would be assigned to them during the actual
experiment. All teams then performed a ten minute practice
session with the "real" REMAN task (i.e., horizontal or vertical
team structure) that they would be performing during the actual
experiment.

In accordance with the characteristics of the synthetic-work
approach, the four TPAB tasks were synthesized into a relatively
realistic work situation that required team members to time-share
the performance of the several tasks. Teams were required to
perform the tasks for a total of three 2-hour performance

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sessions. Within each 2-hour session, the work was divided such that team members were responsible all of the time for monitoring tasks, but only part of the time for the REMAN task. Specifically, each 2-hour session consisted of three repetitions of the following: ten minutes of monitoring performance, thirty minutes of monitoring and REMAN performance.

At the end of the first and second 2-hour sessions, team members completed a subjective workload experience questionnaire and a team cohesion questionnaire. Following the third 2-hour session, subjects filled out both the workload and the cohesion questionnaires, a questionnaire pertaining to "teamness", and a team coordination attitude questionnaire (the same one as given at the outset of the experiment).

Input Variables

Task characteristics

Workload is the task characteristic of interest for the present research. The effects of workload were assessed by observing performance under the levels of the workload manipulation described above. Additionally, the load imposed by task characteristics was assessed in terms of the subjective workload experience of team members. The NASA Task Load Index (Hart & Staveland, 1988) was selected to provide measurement of subjective workload. The NASA-TLX provides a weighted rating of workload along six dimensions: mental demand, physical demand,

temporal demand, performance, effort, and frustration level. Hart and her colleagues (Hart, et al., 1988) developed this scale over the course of sixteen experiments, and have demonstrated it to have a test-retest reliability of .83. Recent reviews have also supported the validity of the TLX as a workload assessment instrument (e.g., Hill, Iavecchia, Byers, Bittner, Zaklad, & Christ, 1992).

Work characteristics

The work characteristic that was of interest in this study was team structure. The effects of structure were assessed by observing processes and performance under two levels of structure: hierarchical (vertical) and non-hierarchical (horizontal).

Individual characteristics

The individual characteristic of interest in this study was the attitudes of team members about coordination. The Team Coordination Attitude Scale (TCAS; Weaver, Bowers, & Morgan, 1992) was employed to measure these attitudes. The TCAS was developed as a modification of the Cockpit Management Attitude Questionnaire (CMAQ; Gregorich, Helmreich, & Wilhelm, 1990). However, Weaver and her colleagues used the Aircrew Coordination Observation/Evaluation Scale (ACO/E; Franz, Prince, Cannon-Bowers, & Salas, 1990) and the team performance literature to modify and expand the CMAQ into the TCAS used here. The TCAS is a forty-four item Likert scale, and based on the results of a

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factor analysis (Weaver, et al., 1992), measures three factors:
coordination, communication, and planning. It also has been
demonstrated to yield an alpha reliability coefficient of .81
(Weaver, et al., 1992).

Team characteristics

One of the team characteristics of interest in this study
was the sense of teamness experienced by team members as a result
of participation in the team in previous trials (i.e., before
achieving performance asymptote, see Figure 4). To measure
teamness, an adaptation of the Trainee Self-Report Questionnaire
(Morgan, Glickman, Woodard, Blaiwes, & Salas, 1986) was employed.
The Trainee Self-Report Questionnaire was developed by Morgan and
his colleagues (Morgan et al., 1986) in their work with Naval
Gunfire Support teams. The Trainee Self-Report Questionnaire was
demonstrated to "reflect the perceptions of behaviors and
performances that are of greatest importance for successful
teams" (p. 50). The Trainee Self-Report Questionnaire was
slightly modified in order to make it appropriate for the more
general team task employed here. This adaptation, called the
Self-Report Questionnaire, was an eighteen item five-point Likert
scale which measured team members' perceptions along the
following dimensions: communication, cooperation/coordination,
power relationships, knowledge of duties, role clarity, and
motivation.

A second, team characteristic, team cohesion, was assessed

using the Modified Sport Cohesion Instrument (Yukelson, Weinberg, & Jackson, 1984). Subjects were required to answer twenty-two six-point Likert scale items that assessed four factors of cohesion: attraction to the group, unity of purpose, quality of teamwork, and valued roles. This cohesion scale has been demonstrated to yield an alpha reliability coefficient of .95 (Yukelson, et al., 1984).

The third team characteristic of interest was team familiarity prior to participation in this experiment. A measure of inter-member familiarity was taken in order to rule out selection errors which might confound the measurement of other team characteristics. To assess familiarity, subjects were given a questionnaire that asked them to assess, on a four-point Likert scale, the degree to which they were already familiar with each of the other four team members.

Throughput Variables

Team process measures were obtained by making audio/visual recordings of all sessions of team task performance. These recordings were coded with respect to communication frequency, directionality, and content. Due to the complexity of communication research, details will not be discussed in this publication (see Bowers, Kline, & Morgan (1992); Kline, Urban, Bowers, & Morgan (1992); for a detailed description of these analyses).

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Output Variables

Team performance was measured in terms of the number of targets engaged, the team score (the summation of the resources required for engaged targets minus the resources required for missed targets), the time to acknowledge targets, and the time to engage targets. Individual performance on the monitoring tasks was measured in terms of response latencies.

Results .

Measures of team score were analyzed using a repeated measures analysis of variance (one score per team for each of six 30-minute team task trials). This analysis yielded a significant trial effect across all teams ($F = 15.63$, $p < .001$). This effect is illustrated in Figure 4.


Insert Figure 4 about here

Subsequent tests indicated that asymptotic performance was obtained by the fifth team task trial (i.e., by the beginning of the third hour of team task performance). Therefore, the results of all analyses reported below are based on post-asymptotic performance (i.e., based upon data collected in the third hour of simultaneous team and individual task performance).

Task Characteristics

A 2 x 2 analysis of variance (workload by team structure)

Figure 4. Team score as a function of trial.
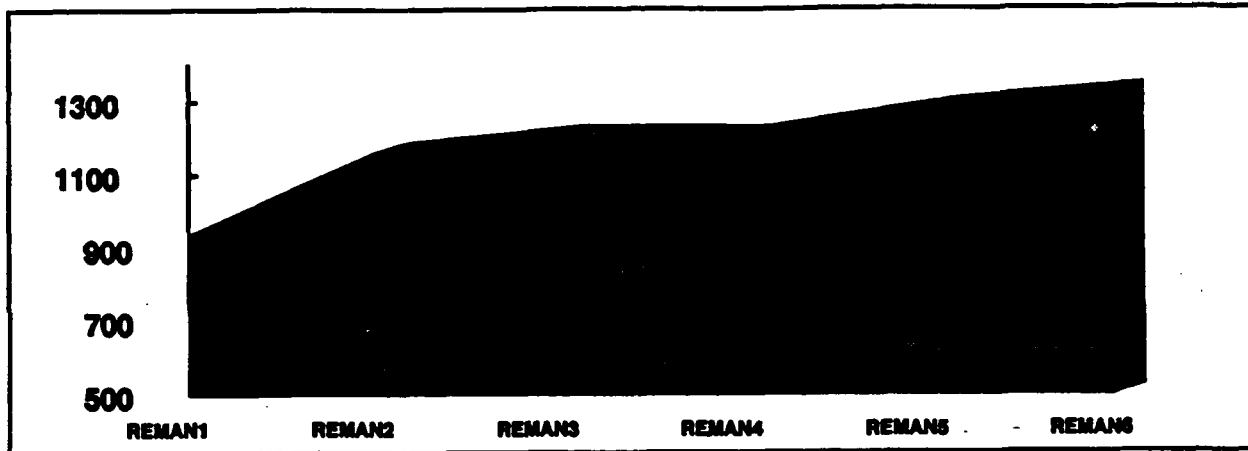
on subjective workload score (as measured by the composite score of the NASA-TLX) indicated no significant effects. Similar analyses performed on the six subscales of the NASA-TLX also yielded no significant difference.

Individual Characteristics

Correlations were computed between the TCAS total score (in which higher numbers correspond to more favorable attitudes toward coordination) and team score. These correlations were computed separately for horizontal and vertical teams, because it was hypothesized that the importance of coordination attitudes would differ as a function of REMAN task structure. Neither the performance of horizontal teams, nor that of vertical teams, was significantly correlated with total TCAS score ($r = 0.74$, and 0.20, respectively). Factor scores were computed for the three factors of team coordination attitudes: attitudes toward coordination, planning, and communication. None of these factor scores was significantly correlated with performance. For horizontal teams, these correlations were: coordination, $r = 0.70$; planning, $r = 0.54$; communication, $r = 0.63$. For vertical teams, these correlations were: coordination, $r = 0.32$; planning, $r = 0.37$; communication, $r = 0.24$.

Work Characteristics

A 2 x 2 analysis of variance (workload by team/task structure) on mean team score indicated a main effect of team structure, such that horizontal teams scored significantly higher

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than vertical teams (F = 4.14, p < .04). This effect is depicted graphically in Figure 5.

Insert Figure 5 about here

A 2 x 2 ANOVA of the number of targets engaged indicated main effects of workload and structure such that low workload teams engaged a significantly greater number of targets than high workload teams (F = 58.54, p < .01), and horizontal teams engaged significantly more targets than vertical teams (F = 12.82, p < .01). A 2 x 2 ANOVA of engagement times indicated similar main effects of workload and structure such that low workload teams engaged targets significantly faster than high workload teams (F= 44.5, p < .01), and horizontal teams engaged targets significantly faster than vertical teams (F = 9.19, p < .01). A 2 x 2 ANOVA on scoring efficiency (number of targets engaged/number of targets presented) indicated that low workload teams achieved a higher efficiency ratio than high workload teams (F = 10.86, p < .01).

Figure 5.   Team score by task structure.
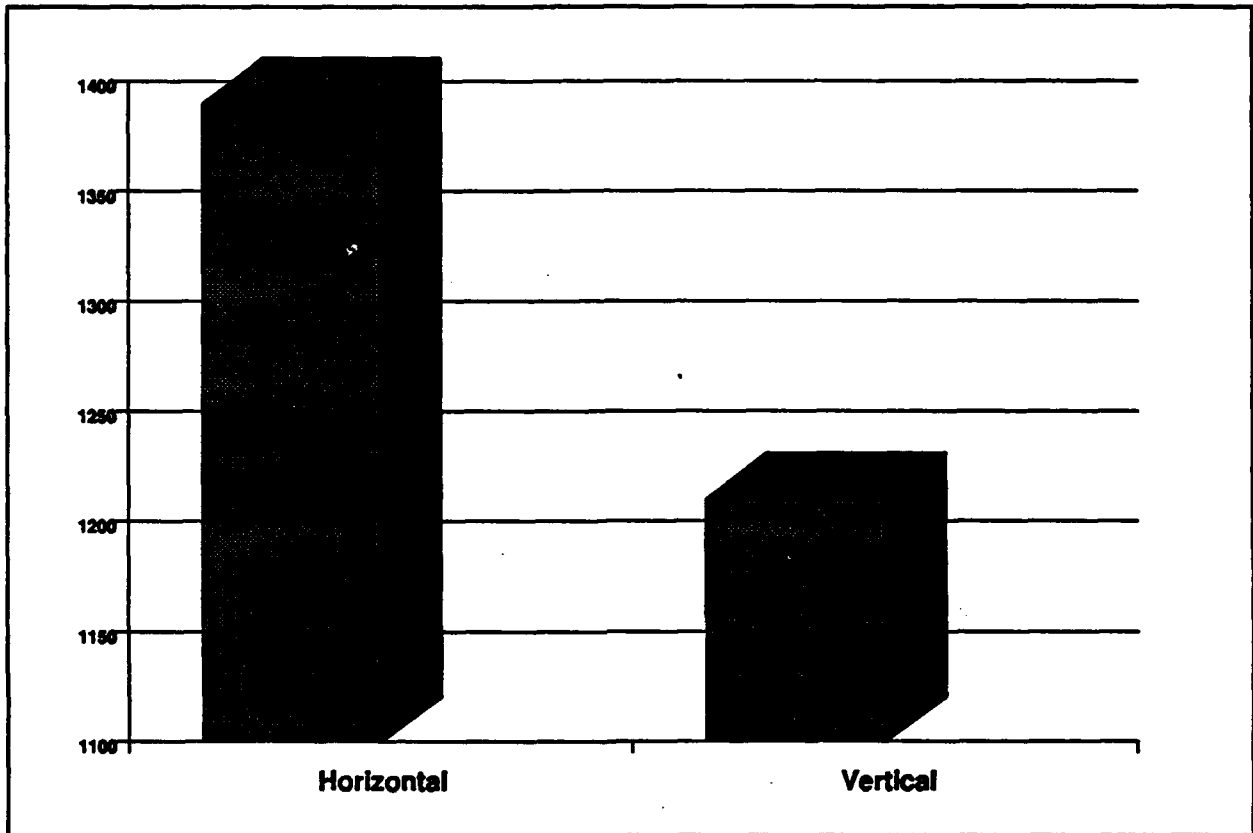
A 2 x 2 ANOVA of average response time to warning lights indicated that the average response time of vertical teams on this task was significantly faster than that of horizontal teams (F = 8.76, p < .01). This effect is illustrated in Figure 6. Similar analyses performed on average response time to blinking lights and probability monitoring indicated no significant effect in either of these tasks.


Insert Figure 6 about here

Correlations were computed between the Self-Report total score (in which higher numbers correspond to a perception of greater teamness) and team score. These correlations were computed separately for horizontal and vertical teams, because it was hypothesized that the importance of teamness would differ as a function of REMAN task structure. For horizontal teams, total Self-Report score was not significantly correlated with performance (r = 0.23). In vertical teams, however, total Self-Report score was significantly correlated with performance (r = 0.82, p < .05).

A factor analysis was performed on data collected with the Self-Report Questionnaire, and the analysis yielded the following four factors: importance of taskwork, importance of teamwork, importance of interdependence, importance of the individual. Correlations were computed between factor scores and team score

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Figure 6. Average reaction time to Warning Lights by task structure.
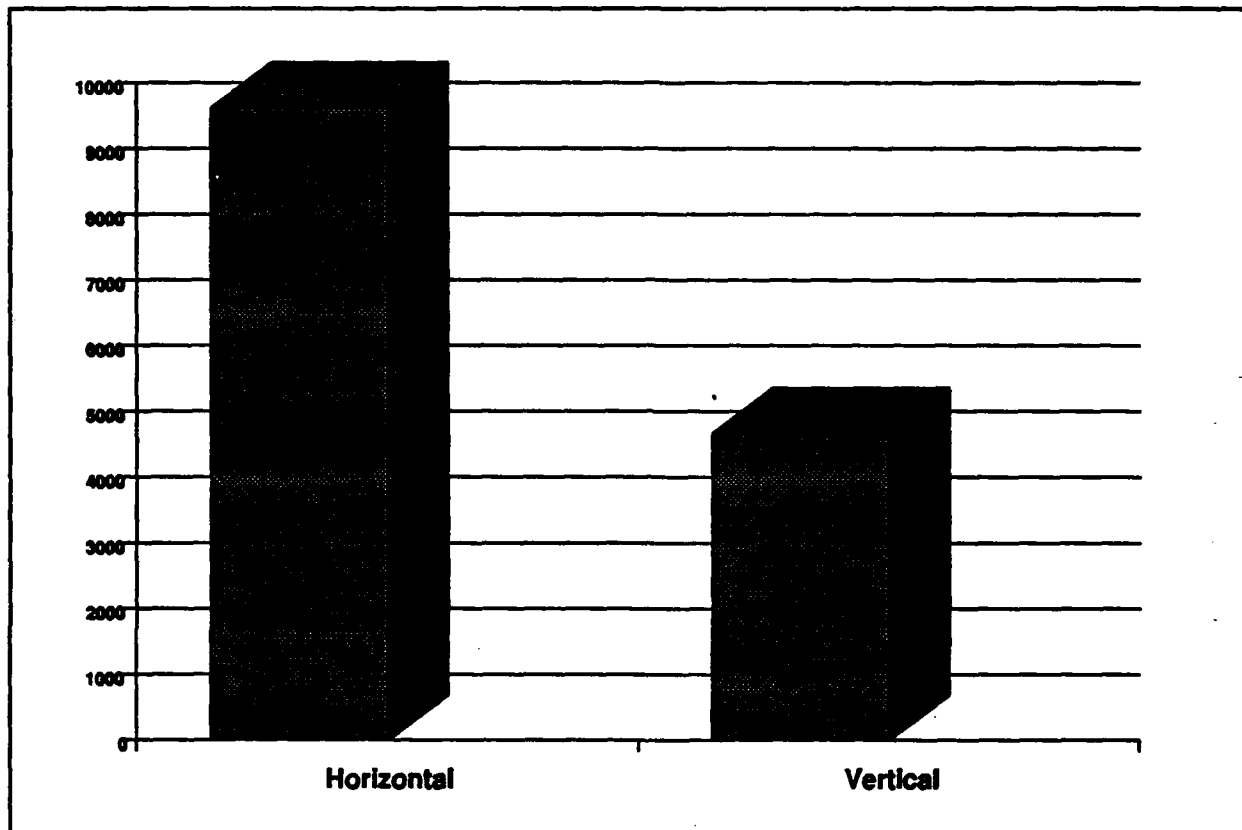
for horizontal and vertical teams. None of these correlations was significant. For horizontal teams, the correlations with team score were: taskwork, $r = 0.53$; teamwork, $r = 0.58$; interdependence, $r = 0.13$; individual, $r = -0.36$. For vertical teams, the correlations with team score were: taskwork, $r = 0.04$; teamwork, $r = -0.08$; interdependence, $r = 0.42$; individual, $r = 0.19$.

Because cohesion data were only collected on high workload teams, a one-way ANOVA was performed to determine the effect of structure on cohesion. This analysis yielded no significant effect. Similarly, a one-way ANOVA was performed to determine if the familiarity of teams differed across levels of task structure. This analysis yielded no significant effect.

Effective vs. Ineffective Teams

In order to determine the relative effectiveness of these twenty-four teams examined here, a median split based on team performance score was performed on the six teams within each cell of the workload by team structure design. Teams scoring above the median were grouped as good performers, and teams scoring below the median were grouped as poor performers. The effects of this two-level grouping variable (i.e., the effects of performance) on various aspects of the team were analyzed using the ANOVA model.

A 2 x 2 x 2 ANOVA (workload by team structure by performance) indicated no significant difference in subjective

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workload score as a function of these factors. A 2 x 2 (team structure by performance) ANOVA on team familiarity (only collected for high workload teams) also indicated no significant effect. A similar 2 x 2 ANOVA was performed on reports of team cohesion (also collected on only high workload teams). This analysis indicated that good performers reported significantly higher levels of team cohesion than poor performers (F = 21.56, p < .01).

Discussion

Task Characteristics

The task characteristic of interest in this study was individual workload, as measured by the NASA-TLX. It was hypothesized that increased workload would be associated with poorer performance (Beith, 1987). The obtained results indicate that subjective workload did not differ across any of the experimental conditions. This difference between the expected and observed effects might be the result of several factors. Specifically, the manipulation that was used to increase workload might not have been effective for the type of task used. Another contributing factor might arise from the fact that the workload scores that were reported are the averages taken across team members. That is, perhaps some of the variability in subjective workload was lost by combining individual subjective workload into a team average.

Individual Characteristics

The individual characteristic of interest in this study was attitudes of team members toward coordination. Specifically, it was hypothesized that attitudes toward coordination would be associated with communication as well as performance. The results fail to provide support for the direct relationship between attitudes and performance. However, the relationship between attitudes toward coordination and communication behaviors is hypothesized to be strong. This hypothesis will be tested and discussed in a future publication specifically addressing team communication processes.

Work Characteristics

The two work characteristics of interest were team structure and workload, both of which are independent variables that were manipulated in this study. Therefore, the effects of each of these manipulations on team performance will be separately discussed.

<u>Team structure</u>. With respect to measures of team performance, it was hypothesized that there would be no effect of structure, but that there would be an interaction between structure and workload, in replication of the study performed by Kleinman and his colleagues (Kleinman et al., 1989). The results indicate that, with respect to both team score and number of targets engaged, a main effect of structure was observed. That is, horizontal teams were at an advantage, regardless of workload

level. This effect of structure might be a function of the specific task differences that resulted from the structure manipulation. The failure to replicate the findings of Kleinman and Serfaty (1989) might also be a function of the increased team size (i.e., five person teams were used here, whereas Kleinman and Serfaty (1989) used two person teams).

These observed effects of structure on performance may be explained by differences in target processing times. Results indicate that vertical teams processed targets more slowly than horizontal teams. This difference might have arisen because more information must be transferred between vertical team members, and this transfer required more time.

The performance differences between horizontal and vertical teams also might have arisen because the vertical teams focused on the individual tasks more than the horizontal teams. The findings show that vertical teams did perform the warning lights task faster than vertical teams. However, this task is only one of the three monitoring tasks that teams were required to perform. Structure effects were not observed in either of the other two monitoring tasks.

Another hypothesis to explain the observed performance difference is that vertical teams might have been less cohesive, which could have led to poorer team performance (when compared to horizontal teams), but better individual performance. Average team scores taken on a cohesion questionnaire, however, indicate

that there was no difference in cohesion between the horizontal and vertical teams.

A final possible explanation for the observed structural performance differences might be that these differences are due to process variables. It is hypothesized that vertical teams might be required to speak more, and this in turn results in slower performance. This hypothesis will be tested and discussed in a future publication specifically addressing communication analysis.

Workload. It was hypothesized that team performance, specifically number of targets engaged and team score, would not suffer as a function of workload, but that there would be a compensatory interaction between structure and workload, in replication of the study performed by Kleinman and his colleagues (Kleinman et al., 1989). However, the current results indicated that low workload teams engaged more targets than high workload teams. (There was no difference in terms of points scored.) Furthermore, high workload teams processed targets more slowly than low workload teams. It can be hypothesized that this longer decision processing time might have arisen because high workload teams are selectively choosing to engage higher value targets. Further analyses are required in order to determine the accuracy of this hypothesis. However, results obtained with respect to score efficiency ratios (i.e., team score divided by the possible score) demonstrate that low workload teams obtained a greater

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proportion of the points available to them. This finding supports the notion that low workload teams emphasized quantity, while high workload teams emphasized quality of performance.

Team Characteristics

One of the team characteristics of interest in this study was teamness, as measured by the Self-Report Questionnaire (Morgan, et al., 1986). In order to explain the observed effects of structure on team performance, it was hypothesized that vertical teams might be less team oriented (i.e., have lower teamness scores) than horizontal teams. This hypothesis is similar to that suggested with respect to team cohesion. The results fail to support this relationship. However, it is hypothesized that teamness influences team processes, which in turn, influence performance. This hypothesis will be tested and discussed in a future publication on team communication.

Another team characteristic of interest in this study was team cohesion. Results indicate that teams who perform well report greater cohesiveness than those teams who perform poorly. It could be the case that greater cohesion leads to better performance. Conversely, this finding might suggest that performance influences reports of cohesion, because cohesion measures were obtained after the teams had completed all performance on the team task.

Familiarity among team members prior to team task performance was another team characteristic of interest. A

measure of inter-member familiarity was taken in order to rule out selection errors which might confound the measurement of other team level factors (e.g., team cohesion or teamness). Results indicate that teams who performed well were neither more nor less familiar with their fellow team members than teams who performed poorly. These results suggest that selection errors arising from prior familiarity were not apparent.

Conclusions

The purpose of the current research endeavor was threefold: 1) to consider the existing literature on team decision making performance in light of a theoretical model, 2) to use this model to generate hypotheses requiring further investigation, and 3) to conduct empirical research to evaluate the resulting hypotheses. The current results indicate that results of previous research might not generalize well to the current task and conditions. Therefore, future research will attempt to isolate those combinations of task characteristics that impact team processes and, ultimately, performance. Additional studies will also be conducted to determine the degree to which these effects generalize across task types.

The current results also provide only partial support for the model of team performance proposed by Tannenbaum and his colleagues. While this might indicate a need to alter the model, it should be noted that the present research sought only to

sample the cells proposed by those authors. As such, additional research is required to test the model more thoroughly.

Finally, there is a need to assess the impact of team throughput variables and the degree to which these variables interact with input variables to determine performance. Past research has demonstrated that alterations in team process can result in an increased ability to perform when faced with stressors. Thus, it might well be the case that performance effects such as those presented above are mediated by the team's coordination processes. Research is currently being conducted to test this assertion.

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